AAA Program:
Overview of the Transmutation Science Activities
LA-UR-02-1002

by

Kemal O. Pasamehmetoglu
Project Leader
Los Alamos National Laboratory
Los Alamos, New Mexico

The main focus of the Advance Accelerator Application program in the U.S is to perform the necessary research and development for the transmutation of spent nuclear fuel. The research program is divided into 5 main areas: Separations, Fuels Development, Systems Analyses, Systems Technologies (mainly focused on identifying and upgrading the necessary facilities to support the research program), and Transmutation Science.

Most of the research that is of interest to the MEGAPIE team is conducted under the Transmutation Science element, which includes the following activities:

High-Energy Physics:	MCNPX code development and high-energy cross-section evaluations.
Reactor Physics:	Spallation target and sub-critical blanket coupling analyses and benchmarks, related code and data development and test facility assessments.
Materials:	Radiation damage on structural materials and impact on structural design criteria.
LBE Research:	Fundamental corrosion, thermal-hydraulic, and instrument development efforts for using LBE as a spallation target and/or nuclear coolant. The emphasis in fiscal year 02 is the operations of the DELTA loop and development of oxygen sensors, calibration standard and corrosion control strategies.

Irradiation Tests: These are presently small-scale low-fluence tests that are conducted in research targets at LANSCE. Long-term objective is to prepare larger-scale, high-fluence tests at the LANSCE beam stop area.

This presentation provides some examples of the activities that are relevant to the MEGAPIE project. These activities include:

- High-temperature testing of irradiated materials and Materials Handbook;
- DELTA loop status;
- Neutron yield and spectrum tests;
- Helium and hydrogen production tests; and
- Oxide layer studies.

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MEGAPIE Technical Review Meeting

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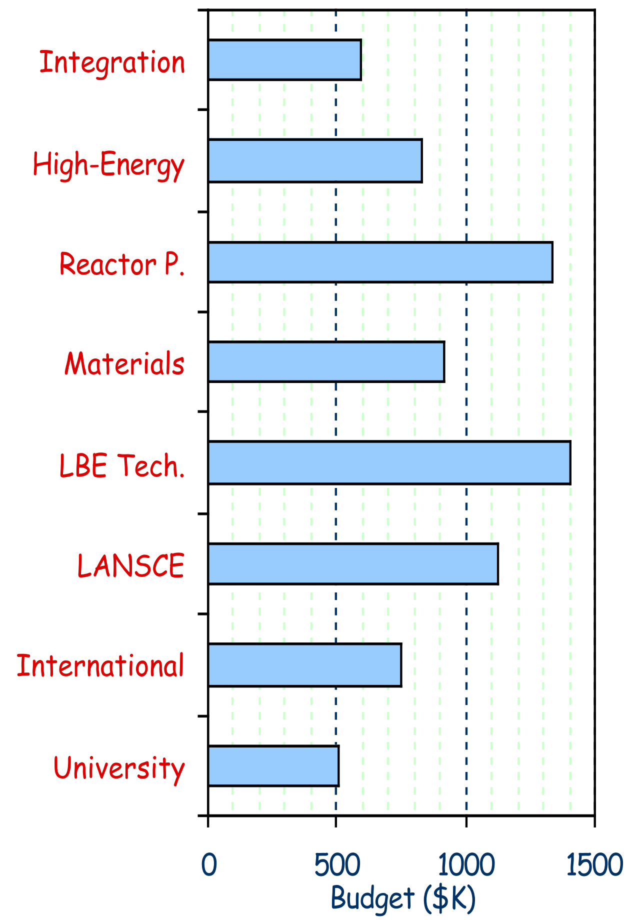
Bologna, ITALY

WHAT ?

FY02 tasks have been defined consistent with the planning packages, budget guidance and the 10-yr R&D plan

TRANSMUTATION SCIENCE

- Integration & Analyses
  - R&D Plans
  - Data req & analysis.
- High-Energy Physics
  - MCNPX
  - Cross-sections
- Reactor Physics
  - Coupling benchmarks
  - Test facilities definition
- Materials - Radiation Effects
  - High-temperature testing
  - Materials handbook
- LBE Technology
  - DELTA loop operations
  - Oxygen control & instruments
- LANSCE Experiments
  - Oxide layer
  - Neutron yield and spectrum
  - He & H production
- International Support
  - MEGAPIE support
  - IPPE target import
- University Support
  - *U. Michigan* • *UC- Berkeley*
  - *U. Texas -Austin* • *NC State*



WHY ?

The main objective is to complete the TRL 6 level (complete proof-of-principle) within approximately 10 years (by ~2010)

PROOF-OF-PRINCIPLE OBJECTIVE

- Validate/verify physics codes and siupporing data (ready for design calculations)
- Demonstrate the key functions and parameters of a target at ~1 MW level.
- Develop/test high-fluence resistant materials
  - Goals: dpa ≥ 100, He/dpa ~10 -100 (target), He/dpa ~ 1-10 (clad),Temp. ~ 400 - 600°C

MAJOR ISSUES

- Accelerator/blanket coupling
- Reactivity control & safety strategy
- Corrosion and control
- Radiation damage
- Thermal fatigue
- Liquid metal embrittlement
- High-energy neutronics data and models
- Materials and coolants compatibility
- Heat transfer/contact angle
- Instrumentation

2000

~2010

TRL 4

- Obtain physics data and develop/upgrade codes
- Define parametric design envelope of the transmuter addressing major issues.

TRL 5

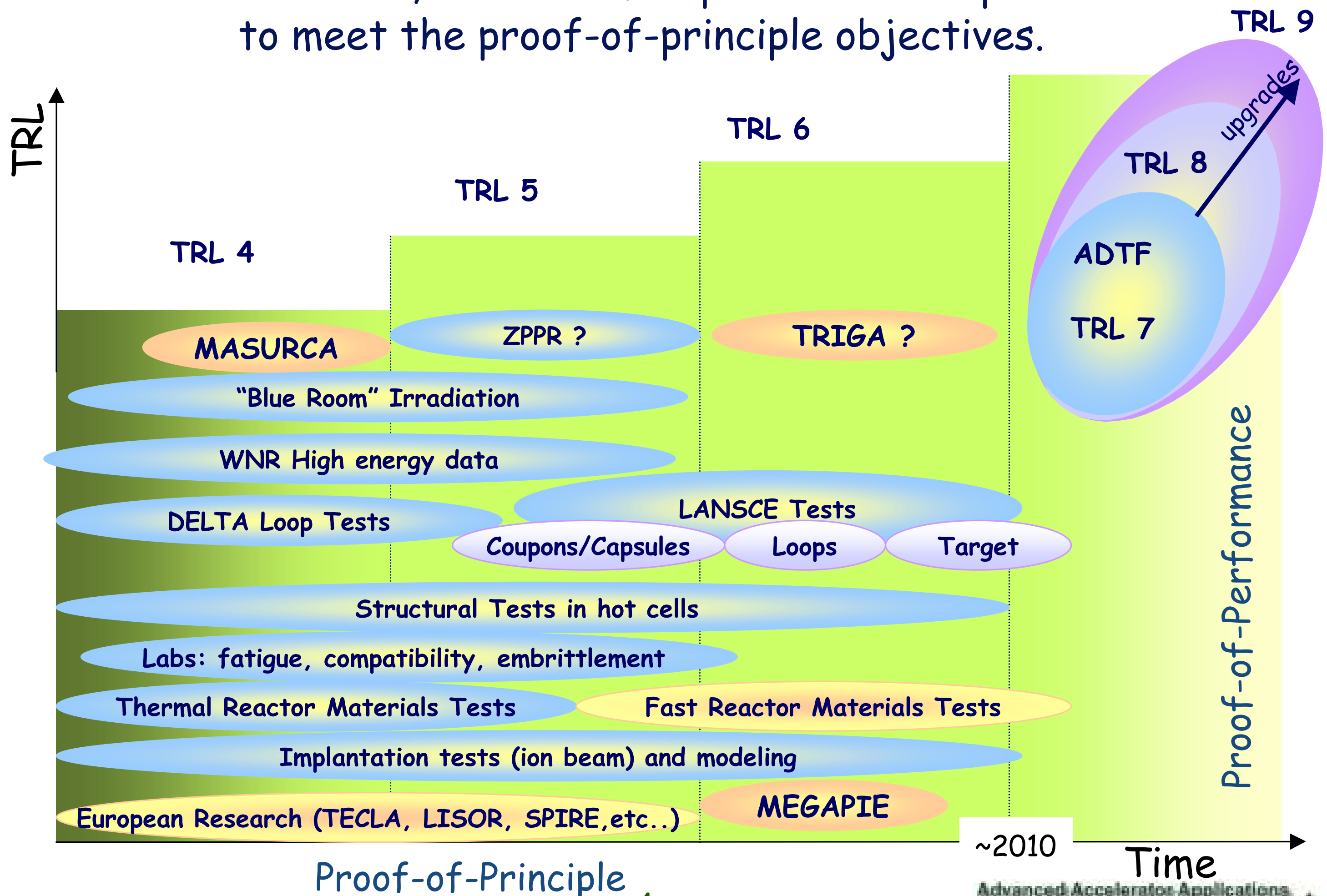
- Compare design codes against separate effect data
- Quantify achievable flux and fluence levels as a function of materials
- Down-select technology options, materials and coolants
- Complete detailed reference design

TRL6

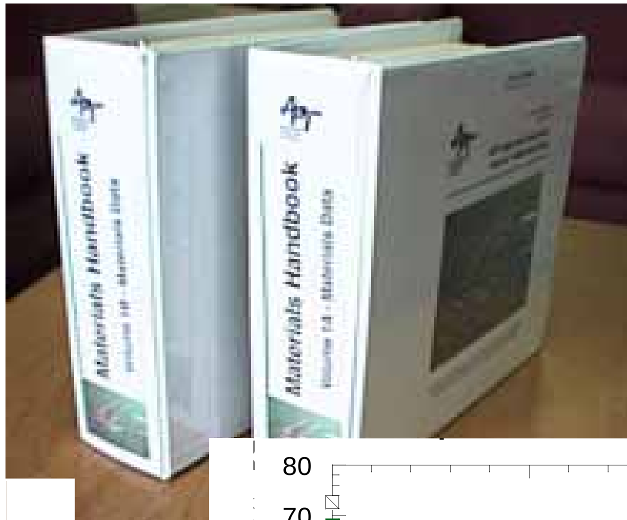
- Verify/validate codes and supporting data (codes ready for design calculations)
- Demonstrate coupling with low fission power
- Demonstrate target and materials at ~ 1MW beam power

HOW ?

Using the existing facilities in the U.S. and International collaboration, a series of experiments are planned to meet the proof-of-principle objectives.



APT Materials Handbook provides design properties for spallation neutron source related materials



Revision 3 Planned for September 2002

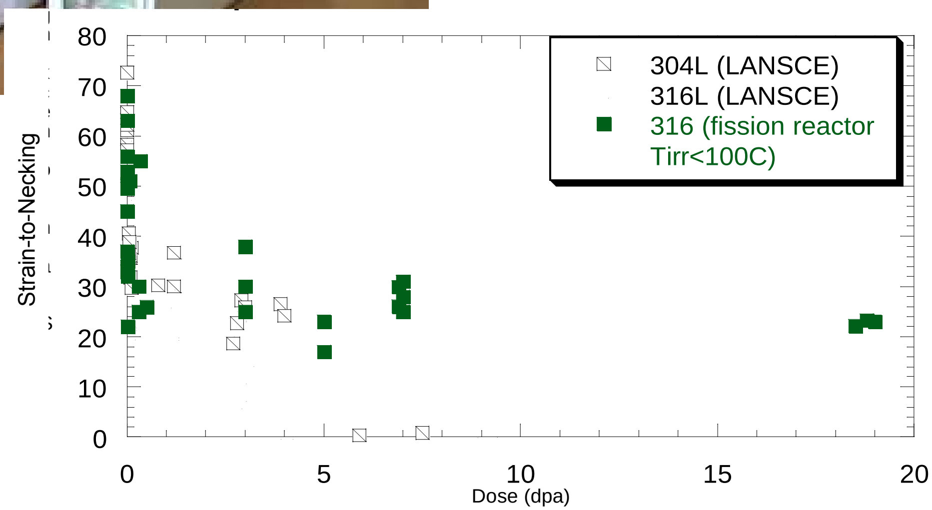
FY02 Plans:

Chapter on 9Cr-1Mo

Revise Tungsten Chapter

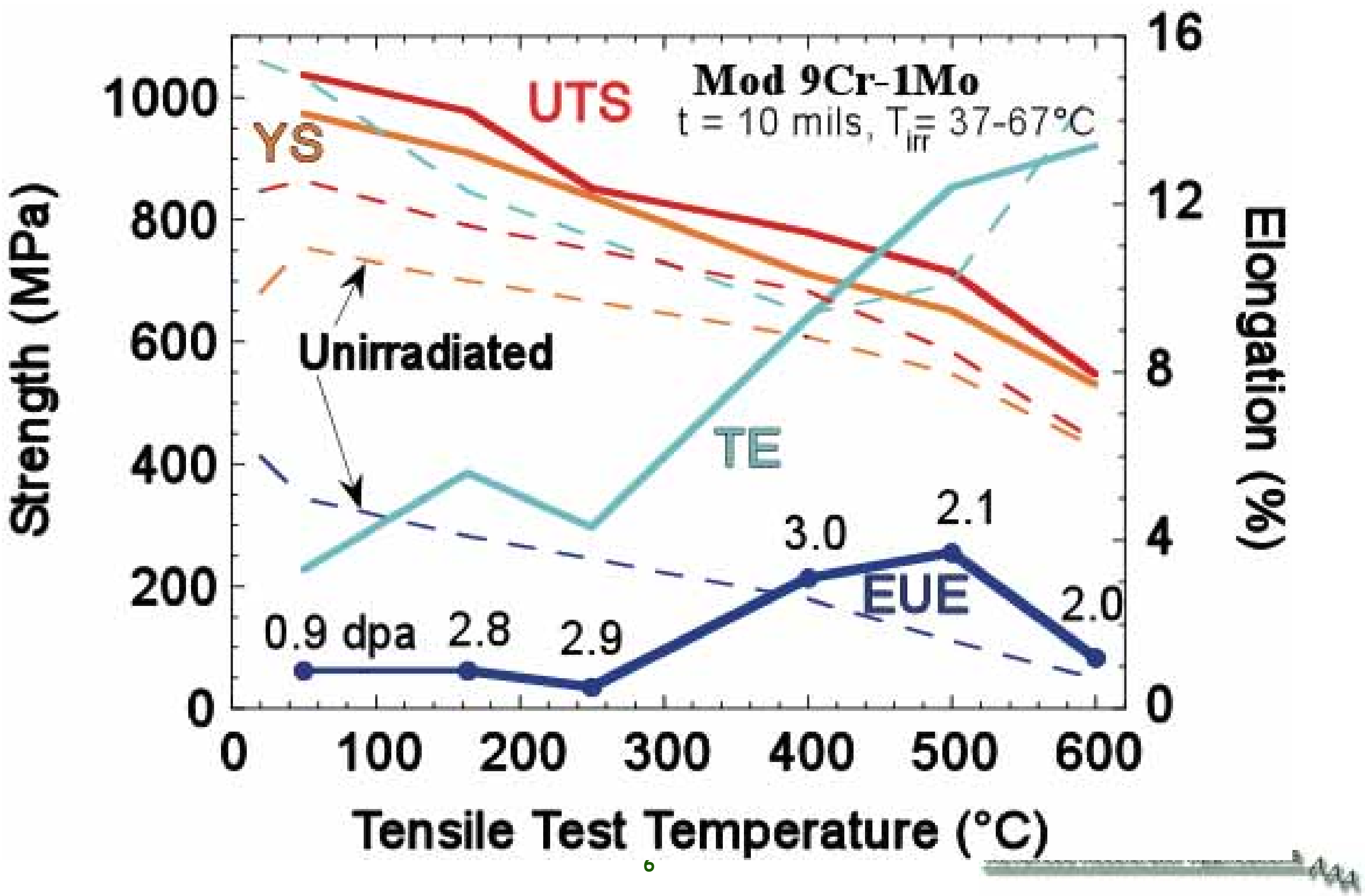
LBE Chapter

DRAFT Tantalum Chapter



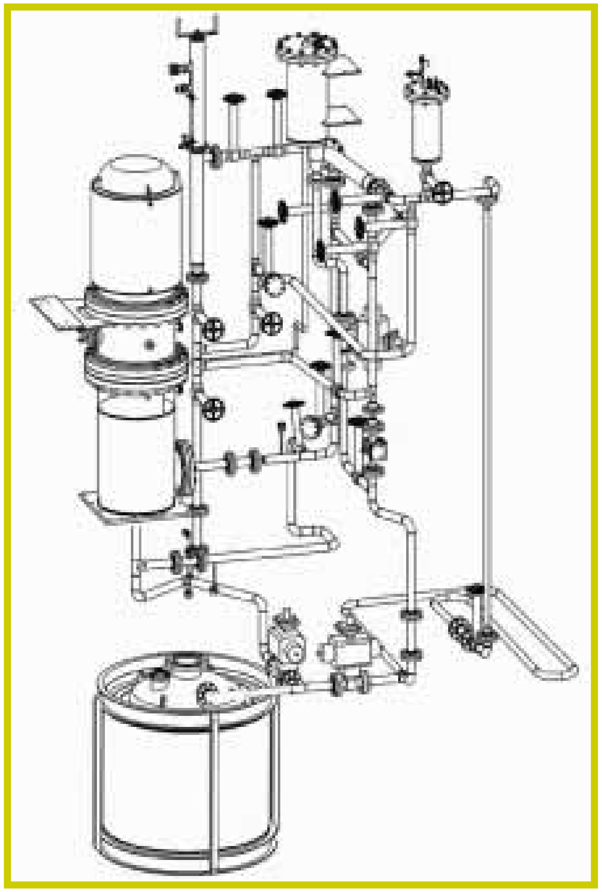
Available in Disc or Hardcopy

Tensile Tests have been Performed at 600°C after irradiation to 2.0 dpa

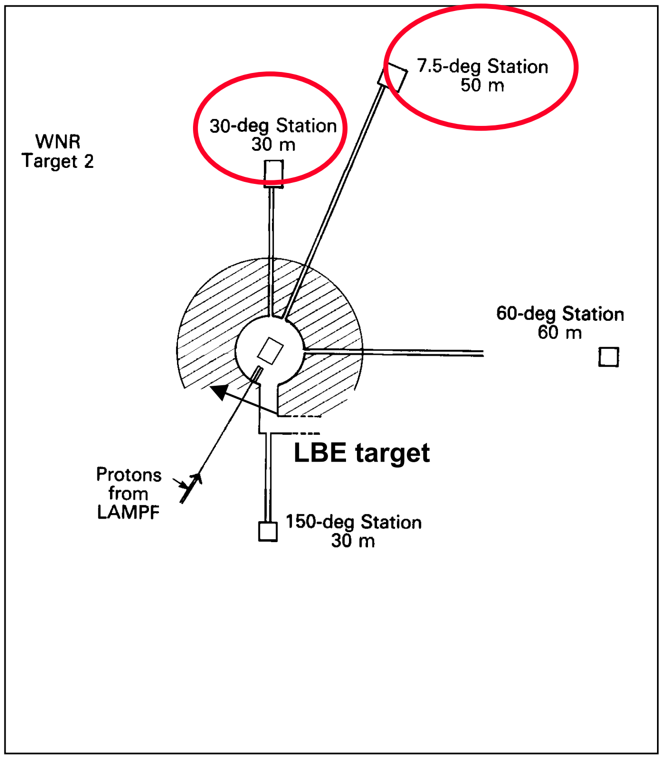


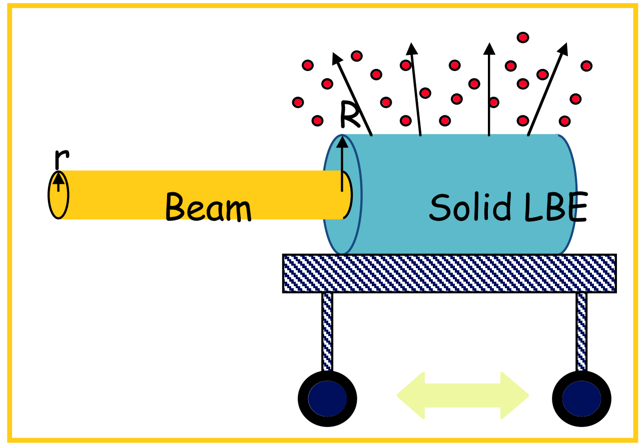
DELTA loop is operational and oxygen sensor and control testing is on-going.

- Design Life ≥ 3 years
- Velocity in test section up to 3 m/s
- Flow rate up to 15 m^3/h
- Maximum temperature 500°C
  - 550°C desirable
- Loop temperature rise ≥ 100°C
- LBE purity ≥ 99.5%
- Oxygen level measurable and controllable.
- Natural convection velocity ≥ 10 cm/s
- Automated data acquisition and control system (DACS)



LBE Target Neutron Yield and Spectrum Experiment





Yield and spectrum= F (E, R, r)

The LBE target of 20-cm in diameter was irradiated in December

- Activation foils packets at 10 cm spacing along length of target
  - Foil packets include Bi, Nb, In, Co, Ni, Fe, Au, Au(Cd), Rh, Ti, Zn, Lu
  - Three irradiations completed:
    - Test run with one foil packet
    - Primary irradiation with 6 foil packets
    - Long irradiation over duration of TOF measurements for 1 packet
  - Foil counting currently in progress

- Neutron Time-of-flight measurements for leakage at angles of 7.5 and 30° w.r.t. incident proton beam
  - Neutron energies from 0.5 to 800 Mev measured with plastic scintillator
  - Energies from 0.01 to 1.0 MeV measured with Li-glass scintillator
  - Flight paths of 60 m at 7.5° and 30 m at 30°
  - Data for both angles and both energies ranges for 3 target positions:
    - Target front face at intersection of flight paths and proton beam
    - Target face 20 cm upstream
    - Target face 40 cm upstream
  - Data reduction currently in progress

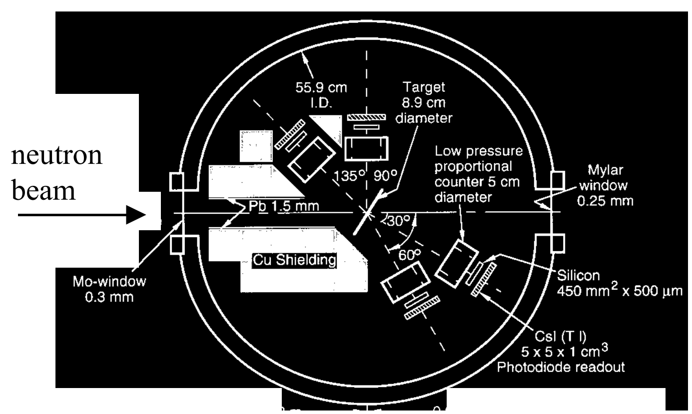
Gas Production Experiments - Status

Approach: Measure production of hydrogen and helium isotopes by energy loss and total energy detectors

- integrate angular and energy distributions to get total gas production cross sections
- obtain microscopic differential data to benchmark reaction model codes so that their predictive capability can be improved

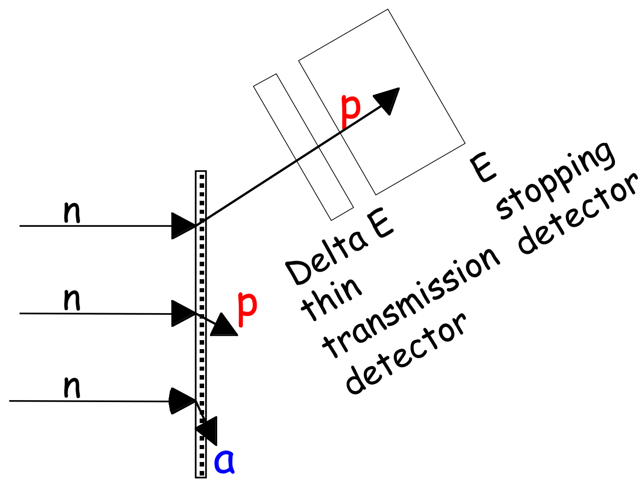
Status: Chamber, detectors, electronics installed in 30-R flight path at WNR for increased neutron flux above 30 MeV

- preliminary data taken on iron -- shows good signal-to-background ratios

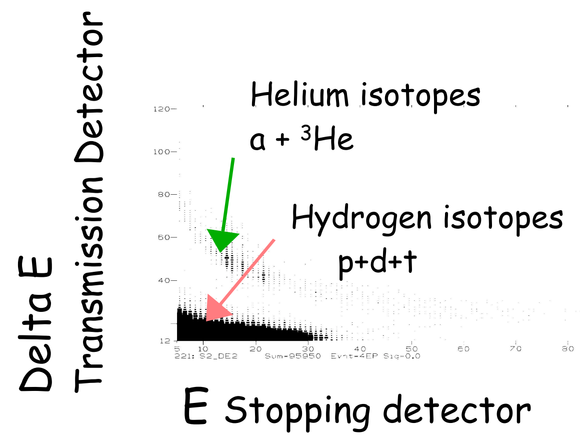


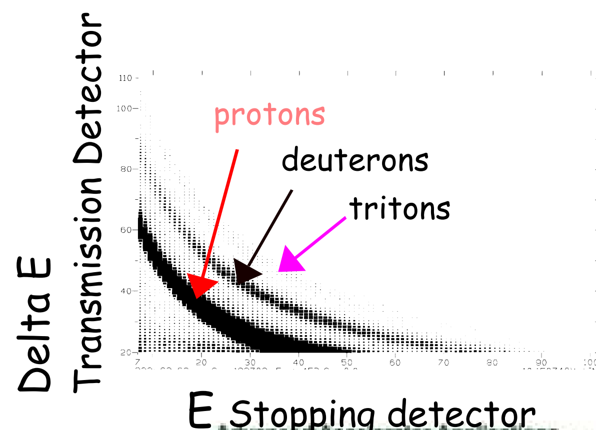
We resolve particles by Delta E-E detectors

(data taken in December 01)



thin iron sample





Total energy of each charged particle is measured by adding Delta E and E signals

Oxide layer characterization and irradiation task has multiple objectives

- **Oxide Characterization (TEM/AES/XPS/SEM)**
  - Literature shows oxide formed in LBE has two layers; these layers may act in a symbiotic manner to protect metal surface from corrosion: inner Cr rich oxide inhibiting oxidation and an outer Fe rich oxide inhibiting Pb corrosion/dealloying.

- **Probe Development**
  - This technique has the potential of being used as a real-time on line probe for corrosion monitoring in a LBE loop.

- **Catastrophic Effects of Proton Irradiation on the Oxide Layer**
  - Blue room (low fluence) irradiation
  - On-line monitoring of the oxide layer capacitance
  - Samples pre-oxidized in LBE over long-time and characterized
    - » Oxides used in the scoping tests may not be representative of the equilibrium oxides.

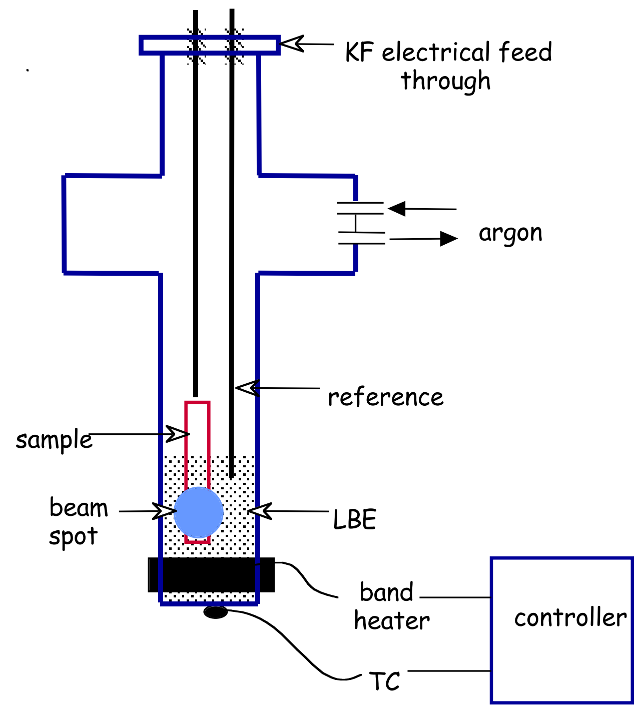
In summer of 2001, some scoping experiments were performed to investigate the irradiation effects on the oxide layer.

- Samples:
  - SS 316L: Fe - 18 at% Cr, 14 Ni, 2 Mn, 3 Mo, 1 Si (austenite),
  - alloy 718: Ni - 19 at% Fe, 18 Cr, 5 Nb, 3 Mo, 0.4 Ti,
  - HT-9: Fe - 12 at% Cr, 1 Mo, 0.6 Mn, 0.5 W (martensite/ferrite)

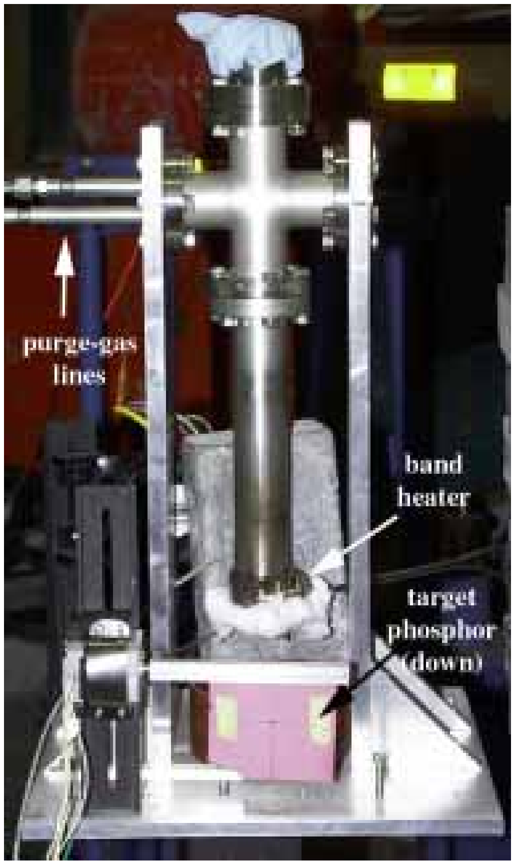
- Sample prep:
  - Polished o 2400p, preoxidized in moist air for 64 hrs. at 800° C.

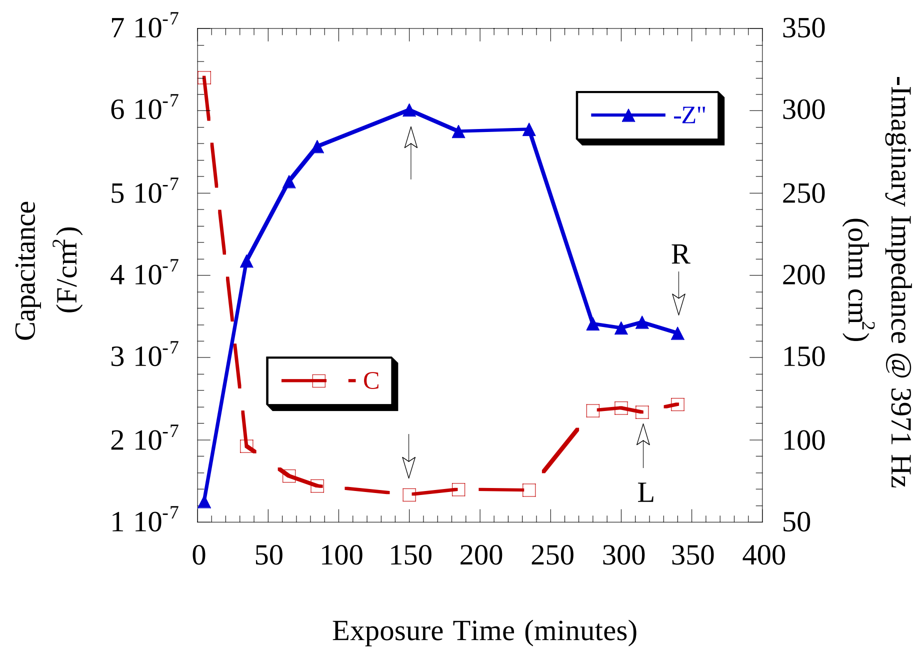
- LBE/experiment temperature: 150° C.

- Beam parameters:
  - 800 MeV, 1.1 μs micropulse spacing, 50 μs gate length, 20 Hz repetition rate, 16 mA peak current. These duty cycle parameters yielded an average proton beam current of 80 nA.



The results for irradiation effects were not conclusive with the atypical oxide layers but the method appears promising.





We are very excited about being part of the MEGAPIE project team!

- Within the context of International collaboration, MEGAPIE project and the supporting research is an important part of the U.S. AAA program.
- The efforts in the AAA program complement and supplement the research in the MEGAPIE project.
- We are looking forward to a fruitful collaboration and looking forward to specific suggestions on how the US efforts can be tailored to better support the MEGAPIE initiative.